

# Little Kaluza-Klein Modes at the LHC

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**Based on:**

- H. D. (BNL), G. Perez (SBU), and A. Soni (BNL)

Phys.Lett.B665:67-71,2008, arXiv:0802.0203 [hep-ph]

- H. D., S. Gopalakrishna (BNL), and A. Soni

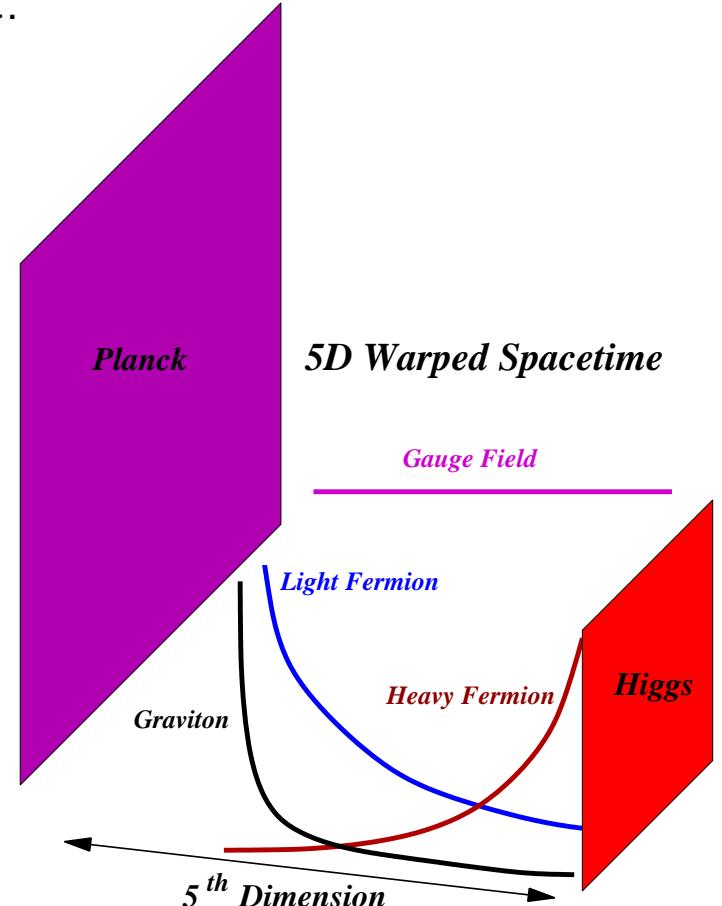
arXiv:0908.1131 [hep-ph]

DOE HEP Site Visit

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# Introduction:

- SM hierarchy problem: Why  $\langle H \rangle / \bar{M}_P \sim 10^{-16}$ ? ( $\bar{M}_P \sim 10^{18}$  GeV)
- Warped 5D **Randall-Sundrum (RS)** model: Randall, Sundrum, 1999
  - Exponential redshift along 5<sup>th</sup> dimension of size  $\pi r_c$  and curvature scale  $k$ .
  - $\langle H \rangle_5 \sim M_5 \sim \bar{M}_P$  and  $e^{-kr_c\pi} M_5 \sim \text{TeV}$  for  $kr_c\pi \approx 35$ .
  - TeV-scale Kaluza-Klein (KK) resonances at LHC.
- SM in 5D RS: geometric explanation of **flavor**.
- Clean (e.g., dilepton) KK signals suppressed.
- **Little RS (LRS)** models: H.D., Perez, Soni, 2008  
 In a model of **flavor**,  $M_5 \sim \bar{M}_P$  not necessary.
  - If  $\text{TeV} \ll M_5 \ll \bar{M}_P$  ( $1 \ll kr_c\pi \ll 35$ )
    - Some constraints are relaxed.
    - Still explain  $\langle H \rangle / M_5 \ll 1$ .
  - Bonus: greatly improved dilepton signals.
    - $q\bar{q} \rightarrow Z' \rightarrow \ell^+ \ell^-$ ;  $\ell = e, \mu$  clean, early data.
  - KK gluons: challenging  $t\bar{t}$  final state.



## Dilepton Little $Z'$ Signals

- LRS truncation factor:  $y \equiv (kr_c\pi|_{RS})/(kr_c\pi|_{LRS})$  ( $y > 1$ )
- $g_{KK}|_{UV} \sim g_4/\sqrt{kr_c\pi}$  ( $q, e, \dots$ ) ;  $g_{KK}|_{IR} \sim g_4\sqrt{kr_c\pi}$  ( $H, t, \dots$ )
- (i) KK modes become narrower:  $\Gamma \sim 1/y$  IR-coupling-dominated
- (ii) Width into light states ( $e^+e^-, u\bar{u}, \dots$ ) grows  $\sim y$
- (iii) Signal  $\mathcal{S}$ :  $\sigma(q\bar{q} \rightarrow Z' \rightarrow \ell^+\ell^-) \propto \overbrace{\Gamma(Z' \rightarrow q\bar{q})}^{\sim y} \overbrace{\text{BR}(Z' \rightarrow \ell^+\ell^-)}^{\sim y^2}$
- (i)  $\oplus$  (ii)  $\oplus$  (iii):  $\boxed{\mathcal{S} \sim y^3}$  and  $\boxed{\mathcal{S}/\mathcal{B} \sim y^4}$  !      Background:  $\mathcal{B} \sim 1/y$  (over width)

- Sensitivity to the UV-brane scale.

$$y \approx 1 \Rightarrow M_5 \sim \bar{M}_P ; \quad y \gg 1 \Rightarrow M_5 \ll \bar{M}_P.$$

- Assume a warped TeV-scale KK mode is discovered.

*Question: Is the hierarchy problem resolved?*

- We may use clean LRS signals to address this question.

IR data (KK)  $\Rightarrow$  UV information ( $M_5$ ).

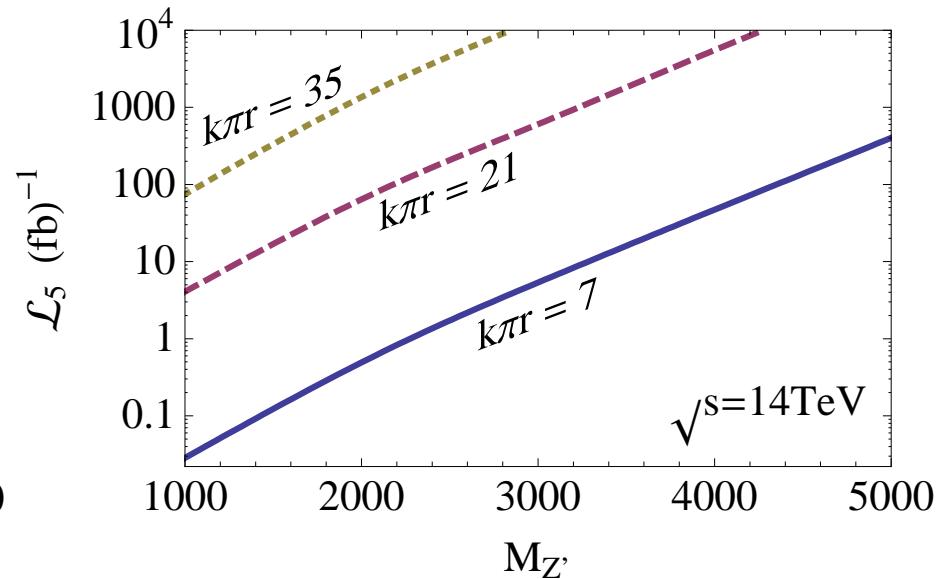
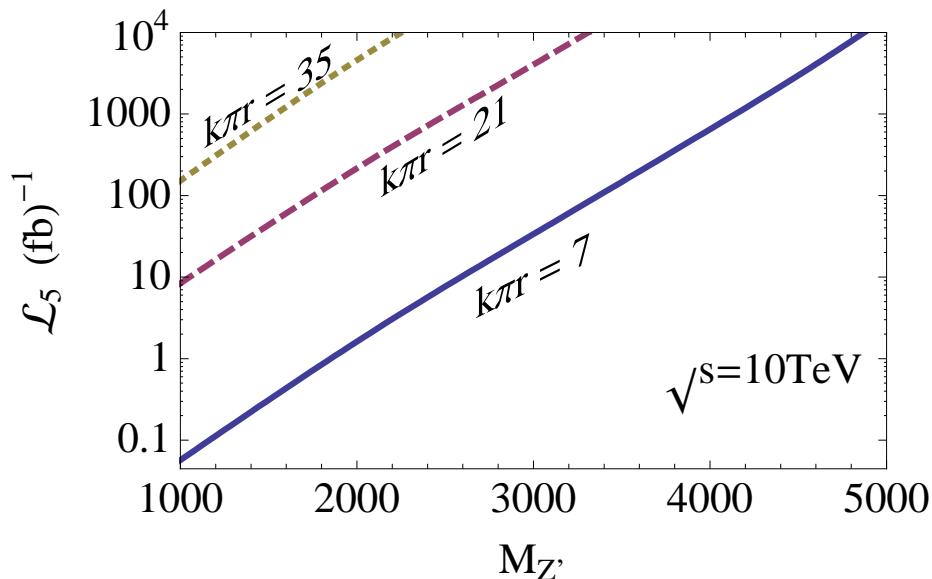
- Holography: Size of *conformal* interval above the weak scale.

ADS/CFT    [Maldacena, 1997](#)

- $M_5 \sim 10^4$  TeV ( $y \approx 5$ ): Reasonable *flavor* physics scale.
- Dangerous operators sufficiently suppressed.
- $y \approx 5$ :  $\mathcal{S} \rightarrow 5^3 \times \mathcal{S}$  &  $\mathcal{S}/\mathcal{B} \rightarrow 5^4 \times \mathcal{S}/\mathcal{B}$     [H.D., Perez, Soni, 2008](#)
- Early (clean) LHC data may probe interesting values of  $M_5$ .

# LHC Reach

H.D., Gopalakrishna, Soni, 2009



$\mathcal{L}_5$ :  $\int L dt$  for  $5\sigma$  signal ( $\geq 3$  events) in  $pp \rightarrow \ell^+ \ell^-$  ( $\ell = e$  or  $\mu$ ).

Precision data:  $Z'$  mass above  $\sim 2 - 3$  TeV.

# Concluding Remarks

- LRS: some unwanted effects suppressed by truncation.
- TeV-scale KK properties sensitive to UV scale  $M_5 \gg \text{TeV}$ .  
TeV data → Microscopic information on underlying theory
- $M_5 \sim 10^4 \text{ TeV} \rightarrow$  reasonable (safe) scale for flavor physics.
- For  $M_5 \sim 10^4 \text{ TeV}$ , 2 (3)-TeV Little  $Z'$  at  $\sqrt{s} = 10(14) \text{ TeV}$  with  $1(4) \text{ fb}^{-1}$ , in clean dilepton channel (early physics).
- With  $M_5 \sim \bar{M}_P$  (original hierarchy): 3-TeV  $Z'$  with  $300 \text{ fb}^{-1}$  at  $\sqrt{s} = 14 \text{ TeV}$  in any channel (some years into the future).